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MUTUAL CHANGE OF ACOUSTIC EMISSION STATISTICAL ENERGY PARAMETERS AT TREATING TOOL WEAR

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Abstract*—The results of experimental studies of acoustic radiation energy during processing tool wear are considered. The regularities of acoustic emission signal statistical energy parameters changes at normal and catastrophic processing tool wear are determined. It is revealed that the regularities of change in the statistical energetic parameters of acoustic emission signals do not observe a characteristic features of the change which are associated with the appearance of a certain type of tool wear. The regularities of experimental acoustic emission signal statistical energy parameters mutual change during normal and catastrophic processing tool wear are determined. It is shown that the ratio of the acoustic emission signal average energy level to the average energy level standard deviation at a given analysis interval is a sensing parameters to the mechanisms and stages of cutting tool wear during materials machining.*

Index Terms—Acoustic emission; acoustic radiation energy; machining; statistical energy parameters; tool wear.

I. INTRODUCTION

At developing verification and diagnostic methods of technological processes machining materials much attention is given to problems of treating tool condition (wear).

This is due by necessity to optimization and control of technological processes parameters for quality assurance of produced items. At research of treating tool wear the analysis of traditional and non-traditional parameters is carried out – cutting forces, temperature, sound spectrum, acoustic emission signals (AE) and others. At the last years a broad complex researches of technological processes machining materials, including and composite materials (CM), is carried out using the registration and processing of AE signals. Method of AE is a dynamic method. It has a low inertia and high sensitivity to submicro, micro and macro processes of materials deformation and destruction. At performing machining operations, the registered AE signals bear considerable amounts of information about the processes that occur in the materials surface layers, taking into account changes in the conditions of contact interaction treated and treating materials. At the same time, significant difficulties arise in the interpretation of registered AE information. This is due to the fact that AE is affected by a large number of factors – technological process parameters, physical and mechanical characteristics of treated and treating materials. One of the influential factors is the treating tool wear. The occurrence and development of tool wear affects the conditions of treated and treating materials contact interaction that results in change of acoustic radiation parameters.

From the point of view developing methods for verification and controlling the machining process, it is of interest to determine the legitimacies of acoustic radiation amplitude and energy parameters change at increasing of treating tool wear.

II. PROBLEM STATEMENT

The purpose of article is to study the mutual change of experimental AE signals statistical energy parameters at treating tool wear.

For achievement the purpose of article the following problems were put: to determine of acoustic radiation energy regularity change at normal and catastrophic treating tool wear; carry out data processing with determination of AE signals statistical energy parameters changes at normal and catastrophic treating tool wear; to determine of experimental AE signals statistical energy parameters regularity mutual change at normal and catastrophic treating tool wear.

III. REVIEW OF PUBLICATIONS

The AE method is used in studies of various operations of machining materials with a traditional structure and CM [1] – [5]. The researches are directed on looking up parameters, which one are possible for using at mining methods of verification,

http://jrnl.nau.edu.ua/index.php/ESU, http://ecs.in.ua

monitoring and technological processes machining materials adaptive control, including the use of neural networks.

The outcomes of researches demonstrate continuity of acoustic radiation and change its parameters at change conditions of contact interaction treated and treating materials. At the same time, on the registered AE signals parameters influence the different factors – technological machining parameters, physical-mechanical characteristics of treated and treating materials [6 - 10]. However, nature of AE parameters relationship with operating of the different factors has a broad band of changes. As demonstrate researches, in many cases the data of relationship are discordant. So, in article [10] it is shown that at increase of machining CM speed there is increase mean square value (RMS) of registered AE signal amplitude. At the same time, in article [11] it is defined that under the set machining conditions increase of cutting speed leads to reduction RMS of AE signals amplitude. In article [9] the AE account, the numbers of AE events, the AE energy were investigated. It is shown that at increase of machining speed the reduction of all studied AE parameters is observed. In article [10] research influence of cutting depth on AE signals RMS amplitude is also conducted. It is shown that at increase of cutting depth there is a linear increase of registered AE signals RMS amplitude. Research influence of machining technological parameters on AE statistical amplitude parameters is conducted in article [7]. It is defined that to increase of machining speed there is a nonlinear increase of AE signal amplitude mean value and RMS amplitude, and also amplitude mean value standard deviation. Thus reduction of amplitude distribution skewness is observed. The amplitude distribution kurtosis has composite nature of change with its gradual reduction. At increase of feed rate and cutting depth dependence of AE statistical amplitude parameters change have composite nature of change. At increase of treating tool wear there is a reduction of AE signal amplitude mean value, AE signal amplitude mean value standard deviation and amplitude distribution skewness. Thus AE signal RMS amplitude and amplitude distribution kurtosis are increase. At research of AE at initial and final machining material stage authors of article [8] have noted that increase of tool wear leads to increase of AE signal RMS amplitude. In article [12] it is shown that increase of tool wear practically does not lead to change of AE signal of amplitude mean value. Thus dependences of accumulation AE signals amplitude mean value, AE signals RMS amplitude, and also the area under AE signals have linear nature of increase. Similar dependences it is observed to a certain level of treating tool wear with the subsequent their nonlinear change. At the same time, increases of wear lead to reduction of AE signal RMS amplitude standard deviation. The similar result is received in article [13].

For increased reliability definition of cutting tool state at machining materials methods of complex data processing - the fractal analysis and analysis of the main component [14] – [16] are used. Joint processing some number parameters - cutting forces, AE signals, vibrations signals is the cornerstone of methods. Such processing of the registered signals allows defining criteria which can be used for a tool state assessment, including also use of neural networks.

Theoretical researches of AE amplitude and energy statistical parameters at treating tool wear for cases of the controlled and not controlled cutting depth are considered in articles [17] – [20]. It is shown that at controlled cutting depth increase of wear leads to increase of AE signals amplitude and energy statistical parameters. In case of not controlled cutting depth increase of wear leads to reduction of AE signals amplitude and energy statistical parameters. However, with increase wear change of increase or reduction AE signals amplitude and energy statistical parameters speed is observed. From the practical point of view, experimental study of influence treating tool wear on acoustic radiation energy statistical parameters mutual change is interest

IV. RESULTS OF EXPERIMENTAL RESEARCHES

At research carried out machining material on the basis Al-Si-Cu. Material passed heat treatment on the mode artificial aging without preliminary tempering. As machining operation, a turning operation was used. The amount of the machining material made: length – 165 mm; diameter – 71.8 mm. Machining material was carried out on the thread-cutting machine TPK 125 HV (Fig. 1). Machining was carried out with use of CD10 plate with cutting inserts Sandvik Coromant from polycrystalline artificial diamond (PCD). Inserts had a corner of sharpening 80^o, a back corner 5^o and radius the tip of the cutter 0.4 mm. Plates of CD10 were established in the CoroTurn 107 holder.

At machining material registration of AE signals with use of acoustic-emissive system was carried out. The AE sensor was installed on the tool holder. AE signal from output of the sensor amplified and arrived on input of analog-digital converter. After conversion AE signal registered in the personal computer. After signal recording its processing and analysis with use of the software was carried out. Software allows to control of AE signals write process, to carry out their processing, to present results in the form of tables and diagrams, to transform data to formats, for use in Windows applications. Applications were used for carrying out mathematical and statistical data processing. At machining material cutting speed made 100 m/min. Cutting depth made 0.1 mm. Feed rate made 0.1 mm/rev. The sampling frequency of the analog input signal was 170 kHz. The maximum volume of recording AE information was 4 GB.

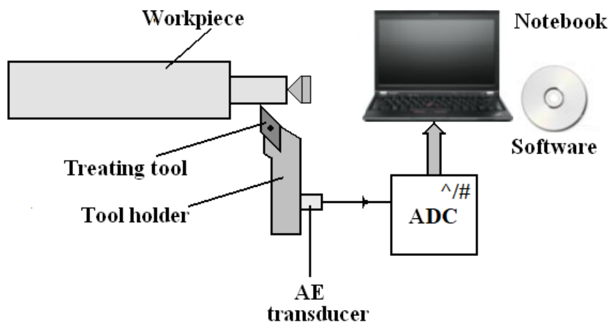


Fig. 1. Experimental test bench

After machining operation completion measurement of tool wear with use of an instrumental measuring microscope MS-4 was taken. The MS-4 microscope has the measuring accuracy of (1.5+0.005 L) microns, where L is the size of the measured part (the basic size for carrying out measurements). The basic size L for measurements made 11.8 mm. Thus the measuring accuracy of tool wear made 1.61 microns.

For carrying out the analysis two typical results of AE signals record (for two tools) – for case a normal and case a catastrophic treating tool wear have been selected. Thus the analysis of acoustic radiation energy was carried out.

The fragment of typical AE signal energy change in time which is registered at an initial stage of machining is shown in Fig. 2. The fragments of energy change in time of typical AE signals which are registered at normal and intensive (catastrophic) treating tool wear at final machining stage are shown in Fig. 3. The value of linear wear at normal tool wear has made 0.05 mm. At treating tool intensive wear has its destruction occurred. The time point of tool destruction is noted in Fig. 3, by a point A.

From Figs 2 and 3 it is visible that upon transition from initial machining material stage to final when tool wear arises and develops, there is a reduction of acoustic radiation energy. However, reduction of AE energy at intensive wear has difficult nature of change, in comparison with a normal treating wear.

Statistical processing of AE signals energy that shown in Fig. 3 in the form of graphs the AE signals energy average level change in time is given in Fig. 4. At carrying out statistical data processing the analysis interval made 1 s. The dependences similar to Fig. 4 are observed and in change of AE signal energy average level standard deviations and their dispersions.

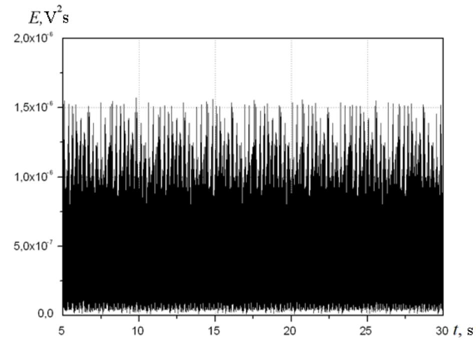


Fig. 2. Graph of experimental AE signal energy change in time at machining material initial stage

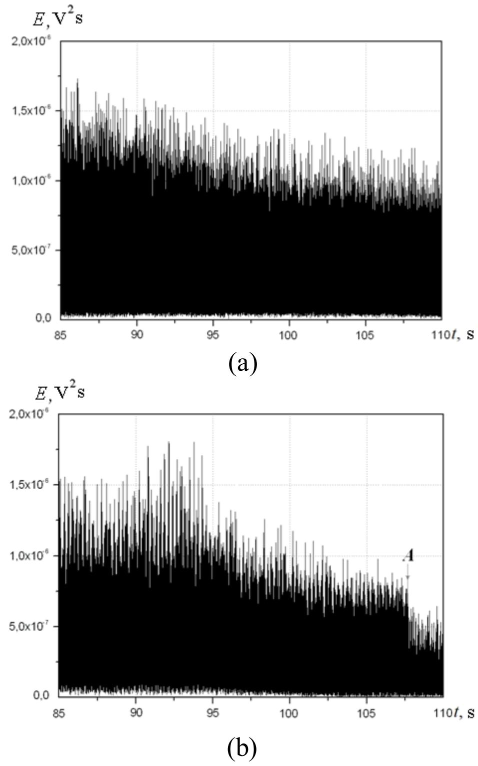
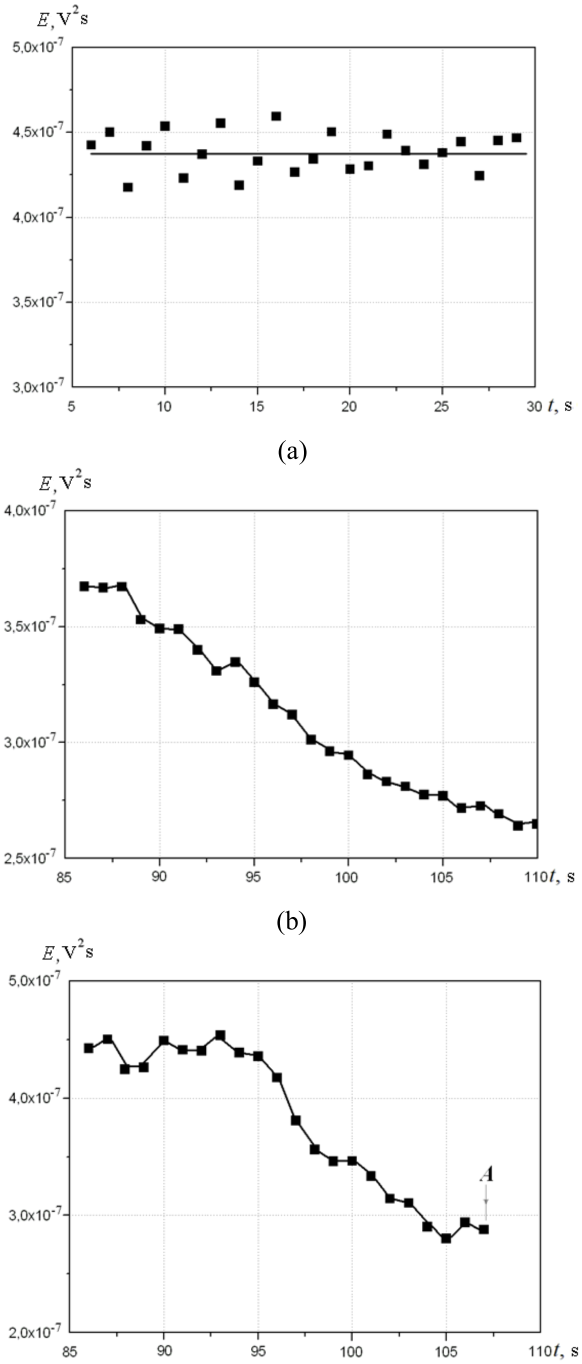


Fig. 3. Graphs of experimental AE signals energy change in time at machining material final stage: (a) at normal treating tool wear; (b) at catastrophic treating tool wear

The received results show next. At machining material initial stage, a certain stability of the registered AE signals energy statistical parameters is observed (Fig. 4a). Stability of AE signals energy parameters is observed before emergence and development of treating tool wear. According to data retrieves, stability of the AE energy parameters at normal wear is observed to 88 s from machining (Fig. 4b). Further there is a reduction of acoustic energy radiation. Stability of AE energy parameters at intensive wear is observed to 94 s from machining (Fig. 4c). Further there is a reduction of acoustic radiation energy. However, as data processing shows, the speed of acoustic radiation energy reduction at normal wear is less, than at treating tool intensive wear. In Figure 5 dependences of AE signals energy reduction at normal and intensive wear are shown, respectively, after 88 s and 94 s machining.



(a) (b) (c)

Fig. 4. Graphs of AE signals energy average level change in times which are shown in Fig. 3

From Fig. 5 it is visible that the speed of acoustic radiation energy reduction at normal wear is less, than at treating tool intensive wear (slope angle of a curve 2 much more, than a curve 1). Calculations show that the speed of acoustic radiation energy reduction at intensive wear in 2.7717 above, then at treating tool normal wear. In too time, on the received dependences features of their change which can characterize transition to the arisen process - normal wear, intensive wear, are not fixed. Thus, as shows data analysis, at different machining stages the advancing change of one AE signals statistical energy parameters – energy average level, energy average level standard deviation, and energy average level dispersion is observed.

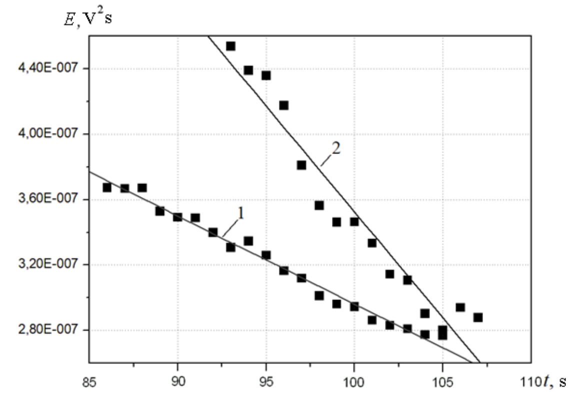


Fig. 5. Graphs of AE signals energy average level change in time at a final machining stage: *1* at normal tool wear (a curve in Fig. 4b after 88 s); *2* at intensive tool wear (a curve in Fig. 4c after 94 s)

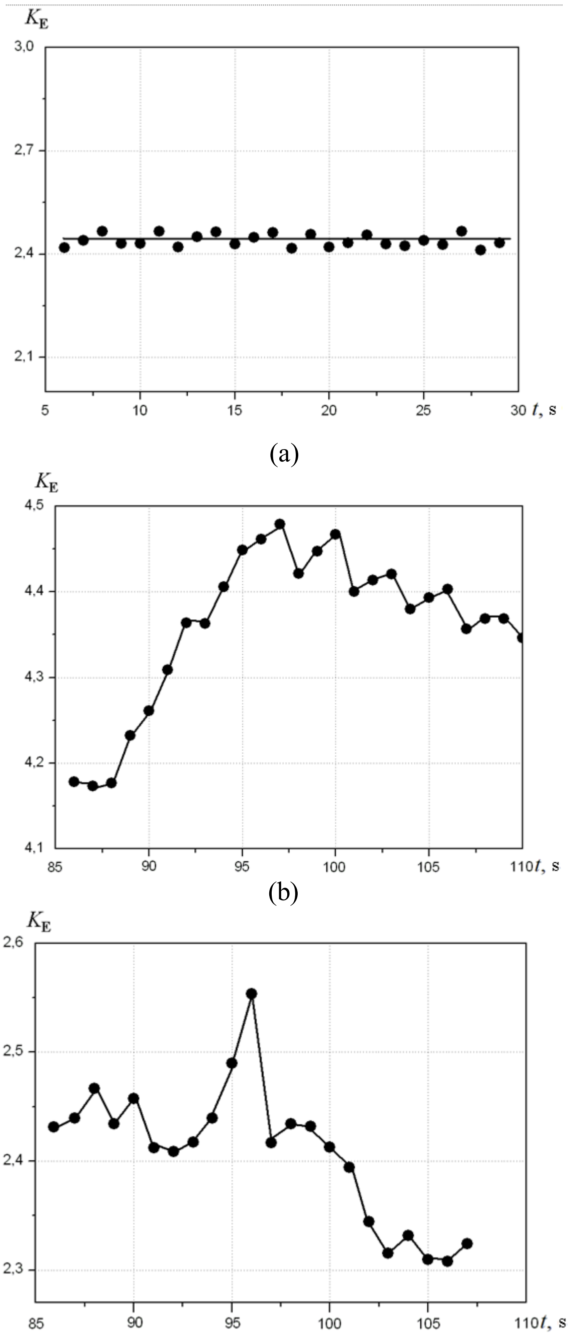
Let's carry out the analysis of AE signals statistical energy parameters mutual change in the form of dimensionless coefficient K_E. The K_E coefficient represents the relation of AE signal energy average level to AE signal energy average level standard deviation on the set analysis intervals

$$K_E = \overline{E} / s_{\overline{E}}, \qquad (1)$$

where $\overline{E}$ is the AE signal energy average level; $s_{\overline{E}}$ is the AE signal energy average level standard deviation.

Results of calculations, it agrees (1), in the form of dependences K_E change in time for AE signals which are given in Fig. 3, is shown in Fig. 6.

Results the carried-out calculations is shown, before emergence of treating tool wear (normal or intensive) a certain stability in value K_E is observed. At a initial stage – Fig. 6a. At a final stage at normal wear up to 88 s (Fig. 6b). At a final stage at intensive wear up to 94 s (Fig. 6c). However after 88 s and 94 s value of coefficient K_E nature change for normal and intensive wear differs.



(a)

(b)

(c)

Fig. 6. Dependences of coefficient K_E change in time, it agrees (1), for AE signals which are shown, respectively, in Fig. 3

At emergence and development of normal treating tool wear increase of value coefficient K_E with the subsequent its saw tooth reduction is observed (Fig. 6b). Such change K_E is caused by that at the initial stage development of normal wear there is an advancing reduction of AE signal energy average level standard deviation, in relation to its average level. At the subsequent development of the process there is an alternation of the advancing reduction of AE signal energy average level or its standard deviation. Emergence of saw tooth change with its gradual reduction probably is connected with emergence of treating tool instant wear staging at the different micro levels of its development. At emergence of intensive wear emission of coefficient K_E value (Fig. 6c) with the subsequent its accelerated reduction before tool destruction is observed. Such change K_E is caused by the advancing reduction of AE signal energy average level, in relation to its standard deviation.

Results of the conducted researches shown that emergence and development of treating tool wear influences on speed of acoustic radiation statistical energy parameters change. Thus are not observed characteristics in their change which are connected with emergence a certain type of tool wear. At the same time, coefficient which the relation of AE signal energy average level to energy average level standard deviation on the set analysis interval is defined is to sensitive parameters to mechanisms and stages of treating tool wear developing. Researches show that in the absence of tool wear the design factor value are stable. Emergence and development of normal tool wear leads to increase of design factor value with the subsequent its saw tooth to change and gradual reduction.

Emergence and development of intensive tool wear leads to sharp emission of design factor value with the subsequent its accelerated reduction before tool destruction. At the time of a sharp increase in the value of K_E, its value increases by 5%, relative to the average value of K_E at the initial stage, followed by a decrease of 5.6%.

Observed features in relation change of AE signal energy average level to energy average level standard deviation on the set analysis interval can be used for control and tool condition monitoring in the processes of machining materials, including also the robotized productions.

IV. Conclusion

Experimental studies result of acoustic radiation energy at emergence and development of treating tool normal and catastrophic wear are considered. The regularities of AE signals statistical energy parameters change at development of normal and catastrophic treating tool wear are defined.

It is shown that lack of tool wear is followed by stable values of AE signals statistical energy parameters. At emergence and development of tool wear reduction of AE signals statistical energy parameters is observed. However, on AE signals statistical energy parameters regularities change are not observed characteristics of change which are connected with emergence of a certain tool wear type. Regularities of experimental AE signals statistical energy parameters mutual change at normal and catastrophic treating tool wear are defined. It is shown that relation value of AE signal energy average level to energy average level standard deviation on the set analysis interval in the absence of tool wear is stable. Emergence and development of normal tool wear is followed by increase of estimated relation value with the subsequent its saw tooth change and gradual reduction in time. Emergence and development of catastrophic tool wear is followed by emission of estimated relation value with the subsequent its accelerated reduction in time before tool destruction.

The results of the conducted researches can be used at developing control and condition monitoring treating tool methods at machining materials, including also monitoring treating tool in the robotized productions. Of further interest are studies the sensitivity of AE statistical energy parameters mutual changes at changing machining technological parameters and treating tool wear.

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С. Ф. Филоненко, А. П. Стахова. Взаємна зміна статистичних енергетичних параметрів акустичної емісії у разі зносу оброблювального інструменту

Розглянуто результати експериментальних досліджень енергії акустичного випромінювання при зносі оброблювального інструменту. Визначено закономірності зміни статистичних енергетичних параметрів сигналів акустичної емісії при нормальному і катастрофічному зносі обробного інструменту. Виявлено, що на закономірностях зміни статистичних енергетичних параметрів сигналів акустичної емісії не спостерігається характерних особливостей зміни, які пов'язані з появою певного виду зносу інструменту. Визначено закономірності взаємної зміни статистичних енергетичних параметрів експериментальних сигналів акустичної емісії при нормальному і катастрофічному зносі обробного інструменту. Показано, що відношення середнього рівня енергії сигналу акустичної емісії до стандартного відхилення середнього рівня енергії на заданому інтервалі аналізу, є чутливим параметром до механізмів і стадій зносу ріжучого інструменту у процесі механічної обробки матеріалів.

Ключові слова: акустична емісія; енергія акустичного випромінювання; механічна обробка; статистичні енергетичні параметри; знос інструменту.

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С. Ф. Филоненко, А. П. Стахова. Взаимное изменение статистических энергетических параметров акустической эмиссии при износе обрабатывающего инструмента

Рассмотрены результаты экспериментальных исследований энергии акустического излучения при износе обрабатывающего инструмента. Определены закономерности изменения статистических энергетических параметров сигналов акустической эмиссии при нормальном и катастрофическом износе обрабатывающего инструмента. Выявлено, что на закономерностях изменения статистических энергетических параметров

сигналов акустической эмиссии не наблюдаются характерных особенностей изменения, которые связаны с появлением определенного вида износа инструмента. Определены закономерности взаимного изменения статистических энергетических параметров экспериментальных сигналов акустической эмиссии при нормальном и катастрофическом износе обрабатывающего инструмента. Показано, что отношение среднего уровня энергии сигнала акустической эмиссии к стандартному отклонению среднего уровня энергии на заданном интервале анализа, является чувствительным параметрам к механизмам и стадиям износа режущего инструмента в процессе механической обработке материалов.
Ключевые слова: акустическая эмиссия; энергия акустического излучения; механическая обработка; статистические энергетические параметры; износ инструмента.

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